Hazard Profile – Avalanche

Introduction[1, 2, 3, 4]

An avalanche occurs when a layer of snow loses its grip on a slope and slides downhill. Avalanches have killed more than 190 people in the past century in Washington State, exceeding deaths from any other natural hazard. One of the nation's worst avalanche disasters occurred in 1910 when massive avalanches hit two trains stopped on the west side of Stevens Pass; 96 people were killed. Avalanches kill one to two people, on average, every year in Washington, although many more are involved in avalanche accidents that do not result in fatalities. Since 1985, avalanches have killed 23 people.

Most current avalanche victims are participating in recreational activities in the backcountry where there is no avalanche control. Only one-tenth of one percent of avalanche fatalities occurs on open runs at ski areas or on highways.

Avalanches occur in four mountain ranges in the state – the Cascade Range, which divides the state east and west, the Olympic Mountains in northwest Washington, the Blue Mountains in southeast Washington, and the Selkirk Mountains in northeast Washington.

The avalanche season begins in November and continues until early summer for all mountain areas of the state. In the high alpine areas of the Cascades and Olympics, the avalanche season continues year-round.

There are two types of avalanches, loose and slab, and two types of slab avalanches, dry and wet. Although the most dangerous avalanche is the slab avalanche, loose slides can and do produce injury and death.

Loose avalanches occur when grains of snow cannot hold onto a slope and begin sliding downhill, picking up more snow and fanning out in an inverted V. Slab avalanches occur when a cohesive mass of snow breaks away from the slope all at once.

Dry slab avalanches occur when the stresses on a slab overcome the internal strength of the slab and its attachment to surrounding snow. A decrease in strength produced through warming, melting snow, or rain, or an increase in stress produced by the weight of additional snowfall, a skier or a snowmobile cause this type of avalanche. Dry slab avalanches can travel 60 to 80 miles per hour, reaching these speeds within five seconds after the fracture; they account for most avalanche fatalities. Wet slab avalanches occur when water percolating through the top slab weakens it and dissolves its bond with a lower layer, decreasing the ability of the weaker, lower layer to hold on to the top slab, as well as decreasing the slab's strength.

In 90 percent of avalanche fatalities, the weight of the victim or someone in the victim's party triggers the slide. An avalanche is like a dinner plate sliding off a table; a slab of snow shatters like a pane of glass with the victim in the middle.

Factors That Affect Avalanche Danger[5]

A number of weather and terrain factors determine avalanche danger:

Weather:

- Storms – A large percentage of all snow avalanches occur during and shortly after storms.
- Rate of snowfall – Snow falling at a rate of one inch or more per hour rapidly increases avalanche danger.
- Temperature – Storms starting with low temperatures and dry snow, followed by rising temperatures and wetter snow, are more likely to cause avalanches than storms that start warm and then cool with snowfall.
- Wet snow – Rainstorms or spring weather with warm, moist winds and cloudy nights can warm the snow cover resulting in wet snow avalanches. Wet snow avalanches are more likely on sun-exposed terrain (south-facing slopes) and under exposed rocks or cliffs.

Terrain:

- Ground cover – Large rocks, trees and heavy shrubs help anchor snow.
- Slope profile – Dangerous slab avalanches are more likely to occur on convex slopes.
- Slope aspect – Leeward slopes are dangerous because windblown snow add depth and create dense slabs. South facing slopes are more dangerous in the springtime.
- Slope steepness – Snow avalanches are most common on slopes of 30 to 45 degrees.

Avalanche forecasting and control is a regular winter expense. The Washington State Department of Transportation's annual budget for removing snow and ice and for avalanche control for the highways that cross the Cascade Mountains is about $44 million. Additionally, the transportation department, ski areas, State Parks and Recreation Commission, National Weather Service, National Park Service, and other agencies, help fund the Northwest Weather and Avalanche Center, which provides daily forecasts throughout the avalanche season for those involved with highway avalanche control and for recreationalists. In FY 2002, the avalanche center received $399,000 in direct funding and in-kind contributions for its operations.

During the avalanche season, the Northwest Weather and Avalanche Center issues daily forecasts as well as special statements and avalanche warnings during times of significantly increased avalanche danger. During the winter and spring of 2001-2002, the avalanche center issued special statements or avalanche warnings on five days in December, seven days in January, one day in February, four days in March, and five days in May.

Selected Avalanches in Washington State – 1910 to Present

Date	Location	Casualties
1910	Stevens Pass	Two trains swept off their tracks, 96 dead.
1939	Mount Baker	6 dead
1958	Silver Creek	4 buried
1962	Granite Mountain	2 dead
1962	Stevens Pass	2 buried
1971	Yodelin	4 dead, several buried
1974	Source Lake	2 dead
1975	Mount St. Helens	5 dead
1981	Mount Rainier	19 dead, 18 injured
1988	Mount Rainier	3 dead
1992	Mount Rainier	2 dead
1994	Mission Ridge	1 dead
1996	Index	3 dead
1996-97	Snoqualmie Pass	Hundreds of travelers were stranded after repeated avalanches closed Interstate 90 during the holidays.
1998	Drop Creek	Snowmobile buried, 1 dead
1998	Mount Rainier	1 climber dead, several climbers injured.
1998	Mount Baker	1 dead
1999	Mount Baker	1 snow boarder and 1 skier dead
2000	Crystal Mountain	1 dead
2001	Twin Lakes	2 dead
2001	Mount Baker	1 dead
2001	Lake Ann	1 dead
2002	Crystal Mountain	1 dead
2003	Snoqualmie Pass	1 snowshoer dead
2003	Mount Baker	1 snowshoer dead, 2 snowshoers injured
2003	Navajo Peak	1 snowmobiler dead

Jurisdictions Most Vulnerable to Avalanche

Based on the location of key transportation routes and recreational areas threatened by avalanche, parts of the following counties are most vulnerable to avalanche (see map, page 5):

Asotin	Chelan	Ferry	Garfield
King	Kittitas	Klickitat	Lewis
Okanogan	Pend Oreille	Pierce	Skagit
Skamania	Snohomish	Whatcom	Yakima

Transportation routes threatened by avalanche[6, 7, 8]

Highway closures due to avalanche can have a significant economic impact on the state. Economists estimate that closing Interstate 90 over Snoqualmie Pass has an economic cost to the state of $750,000 per hour for stalled shipping, lost perishables, and rerouting. (Note: Interstate 90 is the main east-west transportation corridor, carrying the bulk of traffic between western and eastern Washington.) During the winter of 1996-97, there were 276 hours of closure of I-90 over Snoqualmie Pass, 70 percent related to avalanche control and avalanche safety closures; these closures were more than in any other year in recent times. The closures cost the state's economy an estimated $144 million (in 2002 dollars).

The Washington Department of Transportation spends considerable effort each winter keeping the following mountain passes open and free from avalanches:

- King County – Snoqualmie Pass I-90, Stevens Pass US 2.
- Kittitas County – Snoqualmie Pass I-90, Blewett Pass US 97.
- Chelan County – Stevens Pass and Tumwater Canyon US 2.

Passes closed all winter with spring openings that have residual avalanche hazard after they are open are:

- Pierce – Chinook Pass SR 410, Cayuse Pass SR 123.
- Skagit – North Cascades Highway SR 20.

Mountain passes and highways that pose avalanche problems or that have the potential for problems in the worst conditions are:

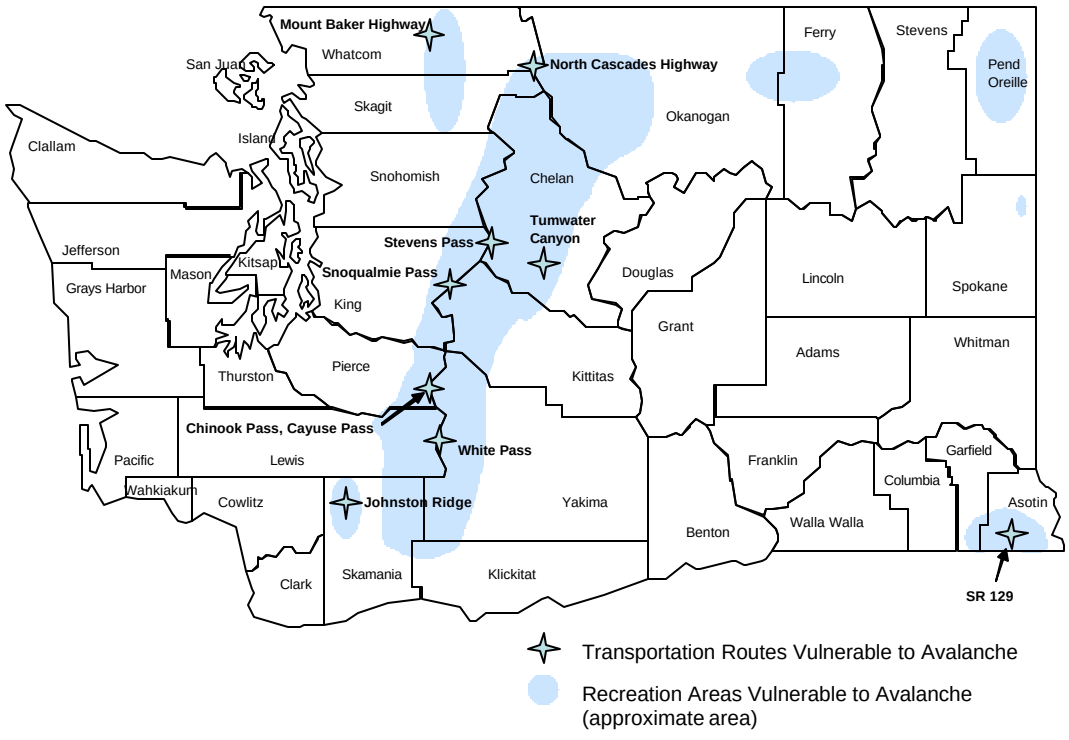
- Lewis and Yakima Counties – White Pass US 12.
- Skagit – Diablo Canyon SR 20.
- Skamania – Johnston Ridge, SR 504.
- Asotin County – SR 129 south of Anatone.
- Whatcom County – SR 542 to the Mount Baker Ski Area.

For general location of these transportation routes, see map below.

Recreation areas threatened by avalanche[9]

With better equipment allowing more people to explore further into the wilderness, areas threatened by avalanche are those accessible by skiers, snowshoers, snowboarders, climbers, and snowmobilers outside developed ski resorts in the mountains of Washington. This includes the areas that people can reach via Sno-Parks (parking lots cleared of snow) in Asotin, Chelan, Ferry, Garfield, King, Kittitas, Klickitat, Lewis, Okanogan, Pend Oreille, Pierce, Skagit, Skamania, Snohomish, Whatcom, and Yakima counties (see map generally depicting areas at-risk to avalanche below).

Areas Vulnerable to Avalanche



State Agency Structures At Risk			PRELIMINARY ASSESSMENT
Number and Function of Buildings	**No. of Affected Staff / Visitors / Residents**	**Approx. Value of Owned Structures**	**Approx. Value of Contents**
Total at-risk buildings: 0	0	0	0

State agencies participating in this plan did not identify any facilities (including critical facilities) as being at risk to avalanche.

However, State Department of Transportation has identified a number of state highways as being at risk to avalanche:

1. Asotin County – SR 129 south of Anatone.
2. Chelan County – Stevens Pass and Tumwater Canyon US 2.
3. King County – Snoqualmie Pass I-90, Stevens Pass US 2.
4. Kittitas County – Snoqualmie Pass I-90, Blewett Pass US 97.
5. Lewis and Yakima Counties – White Pass US 12.
6. Pierce – Chinook Pass SR 410, Cayuse Pass SR 123.
7. Skagit – North Cascades Highway SR 20.
8. Skamania – Johnston Ridge, SR 504.
9. Whatcom County – SR 542 to the Mount Baker Ski Area.

Total at-risk critical faciliites: 0	0	0	0

Four state highways considered emphasis corridors because of their importance to movement of people and freight have been identified as being at risk to avalanche:

1. U.S. Highway 2
2. U.S. Highway 12
3. Interstate 90.
4. U.S. Highway 97

[1] *Washington State 2001 Hazard Identification and Vulnerability Assessment*, Washington State Military Department, Emergency Management Division, April 2001.

[2] Bruce Tremper, *Common Questions about Avalanches*, USDA Forest Service Utah Avalanche Center, <http://www.avalanche.org/~uac/Common-questions.html>, (November 4, 2002).

[3] *United States Avalanche Fatalities by State, 1985-86 to 2002-03 (March 17, 2003)*, Northwest Weather and Avalanche Center, <http://www.nwac.noaa.gov/19852000_aval_fatal_by_state.htm>, (March 25, 2003).

[4] Written communication from avalanche forecaster Mark Moore, Northwest Weather and Avalanche Center, U.S. Department of Agriculture, May 9, 2003

[5] *Avalanche Danger*, Mount Rainier National Park, online fact sheet, <http://www.nps.gov/mora/climb/avalanch.htm>, (November 4, 2002).

[6] Written communication from Terry Simmonds, Washington State Department of Transportation, March 27, 2003.

[7] Tom Paulson, *In Avalanche County, Thinnest of Defenses Hangs Tough*, Seattle Post-Intelligencer, December 27, 2001.

[8] Written communication from Terry Simmonds, Washington State Department of Transportation, March 27, 2003.

[9] Oral communication with avalanche forecaster Mark Moore, Northwest Weather and Avalanche Center, U.S. Department of Agriculture, April 8, 2003.